ENERGETIC REQUIREMENTS FOR GROWTH OF THE JACKASS PENGUIN

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ABSTRACT

Energetic requirements for growth of the jackass penguin (*Spheniscus demersus*) were studied by hand-rearing captive chicks, and by observing growth rates, feeding rates and meal sizes in the field. Daily gain in mass was highest in the period of linear growth (25–55 days). Daily relative growth decreased with age. Food intake and guano production increased from 20–40 days and thereafter remained constant. Relative food intake decreased with age. Digestive efficiency increased with age, and energetic content of guano decreased with age. Chicks in the field grew at a slower rate than the hand-reared birds and were estimated to have consumed approximately half as much food by time of fledging. Feeding of chicks in the field occurred mainly in the afternoon and daily food intake increased with age. It is possible that the slower growth rates in the field may be due to the necessity for parents to guard chicks from predators, after the onset of the chicks' full thermoregulatory abilities.

INTRODUCTION

The jackass penguin (*Spheniscus demersus*) has decreased in numbers since the nineteenth century and appears to be still decreasing (Frost *et al.* 1976). A study of the bird's breeding biology (Cooper in prep.) has indicated that low breeding success is partially due to desertion and subsequent starvation of chicks.

The jackass penguin feeds mainly on pelagic shoaling fish (Rand 1960). These fish are commercially important and it may be that the penguin is competing with the southern African pelagic fishing industry. Frost *et al.* (1976) suggest that the reproductive rate of the penguin would be lowered by any change in the quantity of available food. It is possible that intensive commercial fishing within the feeding range of breeding jackass penguins has caused such a change.

Prior to establishing a relationship between low breeding success and a change in the availability of food, it was necessary to obtain data on the quantity of food needed to rear young successfully. This paper reports on the energetic requirements for growth of the jackass penguin, based largely on data obtained through hand-rearing captive chicks and supplemented by observations made in the field.

There is little published information on the energetic requirements for growth of piscivorous birds and none for penguins. Food intake of captive young of wholly or partially piscivorous birds has been recorded by Dunn (1975*a*), Du Plessis (1957), Harris (1976), Junor (1965, 1972), Kahl (1962, 1966) and Tomlinson (1975). Growth of zoo-bred jackass penguins has been measured by Elanskaya (1946) and Wackernagel (1952).

METHODS

A total of four jackass penguin chicks was collected at Bird Island, Lambert's Bay (32°05'S/ 18°07'E), and at Dassen Island (33°25'S/ 18°06'E), and reared by hand for different periods during 1973–1974. Table 1 gives the age of chicks on collection, date of collection and the period of rearing. The mean fledgling period for 28 single-chick broods on Dassen Island was 73,4 ± 6,5 days (Cooper in prep.). The hand-reared chicks were considered to have 'fledged' at 70 days of age.

TABLE 1

Age in days and period of hand-rearing of jackass penguin chicks.

Chick	*Date collected*	*Age at commencement of rearing*	*Age at end of rearing*	*Period of rearing*
A	5.9.73	20	70	50
B	5.9.73	20	70	50
C	5.12.73	2	18	16
D	5.12.73	5	21	16

The chicks were fed exclusively on a diet of anchovy (*Engraulis capensis*), supplemented with a multi-vitamin and mineral supplement (Vi-daylin M) at five-day intervals. The mean individual mass of the fish was 12,0 g (n = 56). Anchovies form an important part of the jackass penguin's natural diet (Rand 1960), and are caught commercially.

The chicks were hand-fed to near satiation from nine to two times a day, the number of meals decreasing with age. They were not fed at night. The chicks were given whole fish at room temperature, except when very young when they were fed pieces of slightly warmed fish. The food was not pre-digested. Overfeeding caused regurgitation of part or all of the meal, and therefore the chicks could partially regulate their food intake.

Young chicks were kept indoors and were at first artificially brooded, using a 100W light bulb as a heat source. Older chicks (+ 50 days) were kept out-of-doors, but were protected from wind and direct insolation. Chicks were weighed daily in the early morning before being fed. Measurements of culmen, flipper and tarsus + foot were taken at five-day intervals.

Samples (five fish) of the food fed to the chicks, from 25 days of age, were analysed for water and energetic contents at five-day intervals. On the same day excreta (guano) was collected by keeping the chicks individually for 24 hours in cages fitted with wire-mesh floors over aluminium foil trays of known mass. The dry mass of guano produced was obtained through drying the foil trays and their contents to a constant mass in a forced-draught oven set at 50°C. Aliquots of each chick's guano and the food sample were analysed for energetic content using an adiabatic bomb calorimeter.

Field data were collected on Dassen Island and Marcus Island (22°03'S/17°58'E) during

1971–1974. Growth rates were obtained by weighing chicks taken from marked nests at five-day intervals. Meal sizes were estimated by weighing individual chicks several times a day. Feeding rates of chicks of different age classes were observed in colonies of surface-nesting birds. Chicks were grouped into five age-classes, based on culmen length, mass and plumage development. Chicks in the field were weighed to an accuracy of *ca.* 25 g using a spring balance.

RESULTS

Change in mean daily body mass of the hand-reared chicks is shown as a moving average of three (Figure 1). The growth curve is sigmoidal and the most rapid period of growth occurred between 25 and 55 days when increase in mass was approximately linear. The mean daily gain in mass and the mean daily percentage growth, or instantaneous relative growth (Kahl 1962), are shown in Figures 2 and 3 as a moving average of three. Daily gain in mass was highest in the period of approximately linear growth and showed numerous short-term fluctuations. Mean daily relative growth decreased with age.

Growth of culmen, flipper and tarsus + foot is shown in Figure 4. Growth of culmen was linear throughout, while flipper and tarsus + foot increased linearly during the first 40 days and then levelled off.

Mean daily food intake in grams wet mass is plotted as a moving average of three in Figure 5. Food intake increased linearly over the period 20–40 days and thereafter remained approximately level but fluctuated about a 100 g range. Relative food intake (*sensu* Kahl 1962) is plotted as a moving average of three in Figure 6 and showed a steady decrease from approximately 60 per cent to 15 per cent.

The mean mass of dry guano produced over five days is shown in Figure 7. An approximately linear increase occurred from 25–40 days and thereafter production remained constant. Food intake, guano production, energetic values, metabolized energy and digestive efficiency at different ages are shown in Table 2. The energetic value of guano decreased with age. Consequently digestive efficiency increased with age from 25 to 60 days.

The total food intake equals the gross energetic requirement for growth over a 70-day fledgling period. Daily averages are given in Table 3. Estimates were made for all but food intake over the period 0–20 days.

Increase in mass for a total of 18 chicks on Dassen Island is compared with mean daily body mass of hand-reared chicks in Figure 1. Chicks in the field grew at a similar rate to the hand-reared chicks for the first 30 days. Thereafter they grew at a slower rate and a slight loss in mass occurred after 45 days. The mean mass of 542 chicks ringed a few days prior to fledging on Dassen Island was 2 475 $\pm$ 414 g or approximately 500 g below that of the hand-reared chicks at a similar age. Very thin chicks were not ringed. However, a few chicks in the field had greater mass near fledging time than the hand-reared chicks. The heaviest chick weighed in the field had a mass of 3 975 g.

The estimated mass of meals fed to jackass penguin chicks of different age-classes in the field is given in Table 4. Estimated meal size increased with age while relative food intake decreased. This pattern is similar to that observed in the hand-reared chicks (Figures 5 & 6).

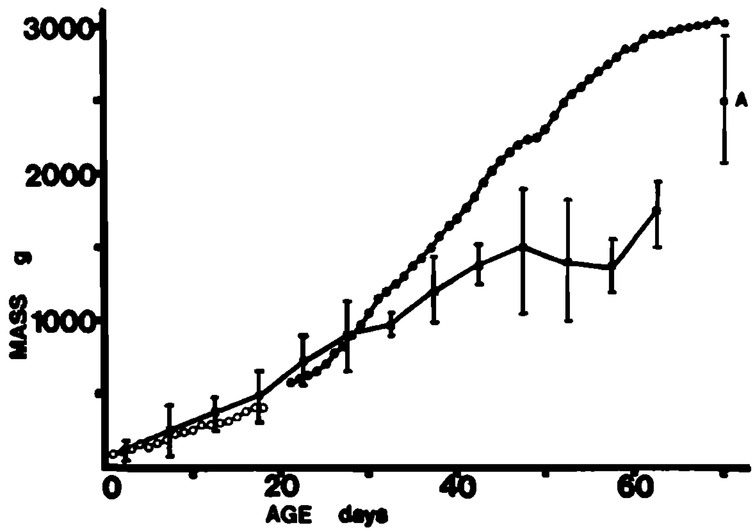

FIGURE 1

Increase in body mass of jackass penguin chicks. Hand-reared chicks are represented by circles, chicks weighed in the field by squares. Vertical bars represent x2 standard deviation. 'A' represents the mean and x2 standard deviation of 542 naturally reared chicks, ringed prior to fledging.

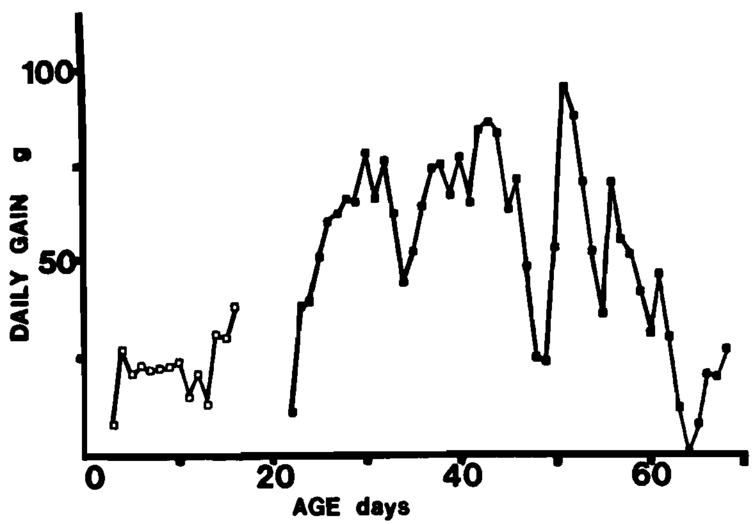

FIGURE 2

Mean daily gain in mass of hand-reared jackass penguin chicks.

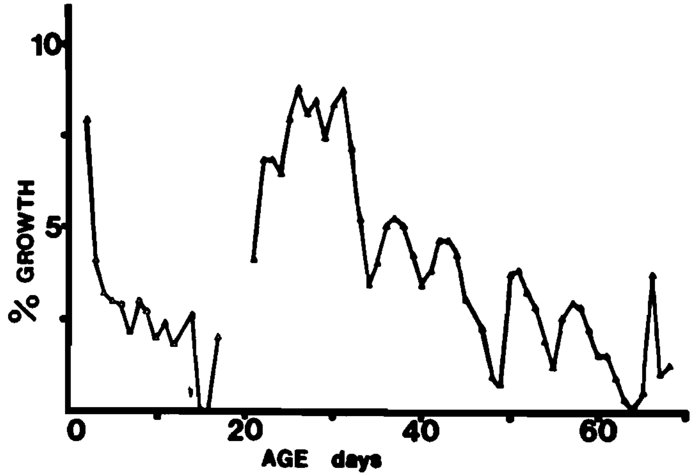

FIGURE 3

Mean daily relative growth of hand-reared jackass chicks $\left(= \frac{\text{mean daily gain in mass}}{\text{mean daily mass}} \times 100\right)$.

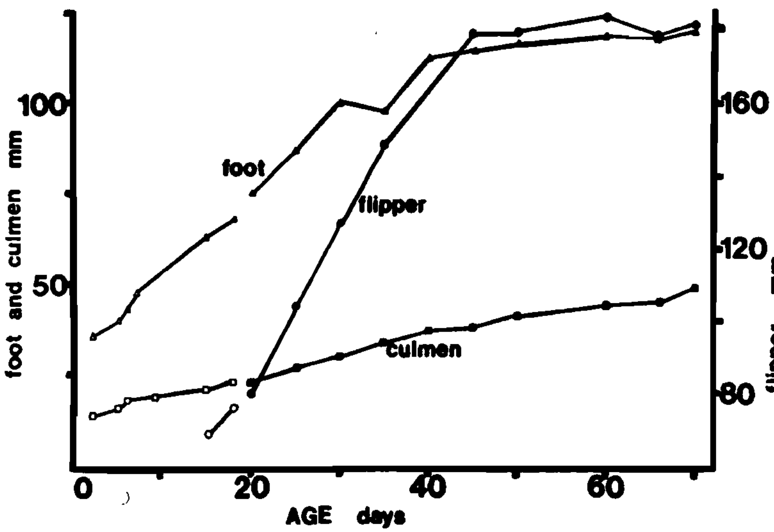

FIGURE 4

Mean growth of culmen, flipper and tarsus + foot in hand-reared jackass penguin chicks.

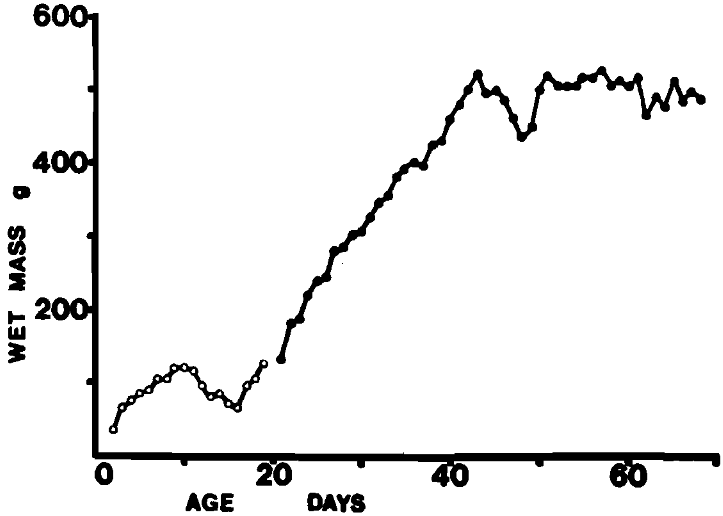

FIGURE 5

Mean daily food intake of hand-reared jackass penguin chicks.

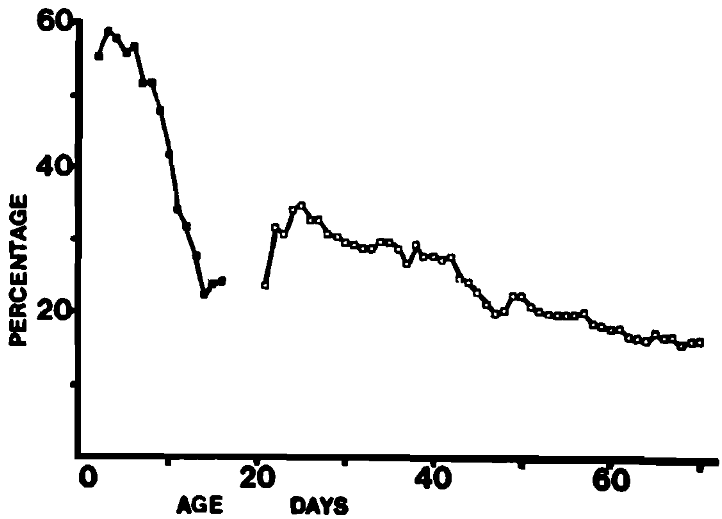

FIGURE 6

Mean relative food intake of hand-reared jackass penguin chicks $\left(= \frac{\text{mean daily food intake}}{\text{mean daily mass}} \times 100\right)$.

TABLE 2

Food and energy intake, guano and energy excreted, metabolized energy and digestive efficiency in hand-reared jackass penguin chicks.

Age (days)	*Food intake (g wet mass)*	*Food dry mass / wet mass ratio*	*Energy content of food (kJ/g dry mass)*	*Energy intake (kJ)*	*Guano excreted (g dry mass)*	*Energy content of guano (kJ/g dry mass)*	*Energy excreted (kJ)*	*Metabolized energy (kJ)*	*Digestive efficiency (%)*
2*	34			285†					
5	67			553†					
10	138			1 139†					
15	106			875†					
20	170			1 394†					
25	225	0,37	25,5	2 127	32	17,6	561	1 566	73,6
30	300	0,34			33		829	2 483	
35	396	0,37	22,6	3 312	55	15,1	829	2 483	75,0
40	424	0,35			61				
45	437	0,37	25,5	4 128	63	13,8	871	3 257	78,9
50	541	0,30			64				
60	560	0,30	23,4	3 940	65	12,6	816	3 124	79,3
65	466	—			59				
70	486	0,29	23,4	3 304	69	11,7	808	2 708	75,5

*Figures are means except for 70 days of age.

†Estimated from mean energetic value of food.

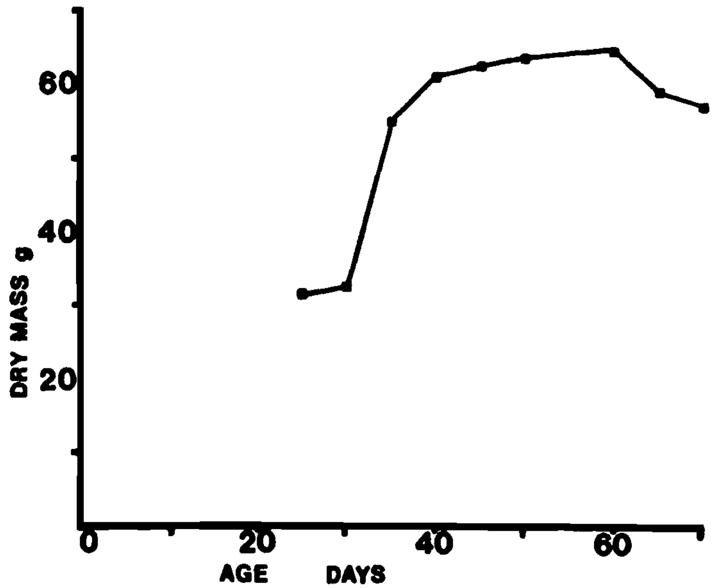

FIGURE 7

Mean guano production of hand-reared jackass penguin chicks, measured over five-day periods.

TABLE 3

Total and daily average food and energy intake, guano and energy excreted, metabolized energy and mean digestive efficiency in hand-reared jackass penguin chicks over 70 days of growth.

	Food intake wet mass	*Energy intake*	*Guano excreted dry mass*	*Energy excreted*	*Metabolized energy*	*Digestive efficiency*
	(*g*)	(*kJ*)	(*g*)	(*kJ*)	(*kJ*)	(%)
Total	22 696	186 255	2 887	45 931	140 324	—
Daily average	324	2 659	41	657	2 002	75,3

However, food intake of the hand-reared chicks was approximately twice that observed in the field (Table 2). Total food intake over the period 0–70 days of age in the field can be estimated to be about 11,5 kg from data presented in Table 4. The hand-reared chicks were fed 22,5 kg over the same period.

TABLE 4

Estimated mass (g) of meals fed to jackass penguin chicks on Dassen Island, 14–16 November 1974.

Estimated age class (days)	*21–30*	*31–40*	*41–55*	*56–65*	*65+*
A Mean gain in mass of chicks fed between 14h00 & 19h00	108 ± 52(6)*	131 ± 108(12)	160 ± 134(12)	170 ± 132(5)	206 ± 101(9)
B Mean loss in mass of chicks not fed between 14h00 & 19h00	18(2)	44 ± 23(4)	54 ± 22(7)	58 ± 13(6)	25(2)
Estimated meal size (A + B)	126	175	214	228	231
C Mean mass (g) of chicks at 14h00	920 ± 205(8)	1 574 ± 254(16)	2 317 ± 225(19)	2 625 ± 217(11)	2 759 ± 329(11)
Relative food intake (%) $\left(\frac{A + B}{C} \times 100\right)$	13,7	11,1	9,2	8,7	8,4

*Means and standard deviations; sample size in parenthesis.

The mean number of attempted feedings of chicks of different age-classes in the field is given in Tables 5a and 5b. Little feeding occurred in the morning or at night and approximately 85 per cent of the feeds were given between noon and sunset. This high percentage validates the method used to estimate daily food intake (Table 4). No clear relationship was observed between number of attempted feedings and age class, but the sample size in each age class was small.

TABLE 5

Mean number of attempted feedings of jackass penguin chicks.

(a)

Dassen Island, 2–3 December 1973.

Estimated age class (days)	*Morning (04h30–12h00)*	*Afternoon (12h00–20h30)*	*Total (16 hours)*	*Attempted feedings in afternoon, %.*
1 – 20 (1)*	9,0	25,0	34,0	73,5
21 – 30(4)	0	7,8	7,8	100,0
31 – 40(7)	0,7	10,0	10,7	93,5
56 – 65(1)	0	14,0	14,0	100,0
65 + (4)	3,8	5,5	9,3	59,1
1 – 65 + (17)	1,7	9,5	11,2	
Total no. attempted feedings observed in 16h	29	162	191	84,8

*No. of chicks in each age class in parenthesis.

(b)

Marcus Island, 9–11 January 1974.

Estimated age class (days)	*Morning (05h00–12h00)*	*Afternoon (12h00–20h00)*	*Night (20h00–05h00)*	*Total (24 hours)*	*Attempted feedings in afternoon, %.*
1 – 20(2)*	0	2,3	0	2,3	100,0
21 – 30(4)	1,4	5,1	0,5	7,0	73,2
31 – 40(1)	0	6,0	0	6,0	100,0
41 – 55(6)	0	5,8	0,5	6,3	88,5
56 – 65(5)	0,5	6,7	0,8	8,0	88,5
65 + (5)	0	7,1	0,4	7,5	94,7
1 – 65 + (23)	0,3	5,9	0,5	6,7	
Total no. attempted feedings observed in 48h	16	269	22	307	87,6

*No. of chicks in each age class in parenthesis.

DISCUSSION

Jackass penguin chicks fed by their parents in the Moscow Zoological Park reached a mean mass of 2 250 g at 70 days of age (estimated from data in Elanskaya 1946). At Basel Zoo chicks were fed by hand to satiation seven to five times a day and attained a mass of 4 250 g in 70 days (Wackernagel 1952). These results agree broadly with the findings given here: hand-reared chicks grew faster, fledged at a greater mass and consumed more food than chicks reared by their parents. Some chicks in the field, however, achieved a fledging mass greater than that of the hand-reared chicks. In the field, two-chick broods grew more slowly than single-chick broods, as reflected in the significantly longer fledging period of the former (Cooper in prep.).

The rate of growth observed in the hand-reared jackass penguin chicks increased from approximately 25 days of age, when the chicks attained full development of their second (post-natal) downy plumage. At about this age chicks also attain mature thermoregulatory powers, and they are independent of parental brooding (Erasmus & Smith 1974). Thereafter, theoretically, chick-growth could be increased substantially as a result of both parents foraging at the same time. However, chicks are not normally left alone until approximately 40 days of age and when they are capable of protecting themselves independently (Cooper in prep.).

The need for parents to protect their chicks from attack by predators, such as the kelp gull (*Larus dominicanus*) (Cooper 1974), and from other penguins, may partially explain the slower growth rates observed in the wild, since only one parent foraging at a time may not be able to feed the chick at a rate commensurate with that attained by hand-rearing.

In the absence of their parents, jackass penguin chicks do not always form crèches. Crèching is normal in most or all surface-nesting penguin species, and the behaviour provides chicks with some protection from predators (Pettingill 1960). Those jackass penguin chicks which do gather into groups tend to be thin. The absence of both parents early in the rearing period appears to be related to food shortage. However, the presumed increase in the jackass penguin's surface nesting habit, brought about by the removal of guano deposits by man (Frost *et al.* 1976), may have resulted in an increase in the incidence of crèching behaviour in a species which normally nests in burrows. Chicks left on their own in burrows are better protected than those in surface nests (pers. obs.).

There is little published data on the digestive efficiency of growing birds. Dunn (1975*a*) found an increase with age (from 80–88 per cent) in the double-crested cormorant (*Phalacrocorax auritus*). Increases also occurred in hand-reared Cape gannets (*Sula capensis*) (Cooper in prep.). In non-piscivorous species, increases have been noted in the black duck (*Anas rubripes*) and the American coot (*Fulica americana*) (Penney & Bailey 1970), and in the house sparrow (*Passer domesticus*) (Blem 1975).

Digestive efficiency of hand-reared jackass penguin chicks increased between 25 and 60 days of age. Values are lower than that obtained by Dunn (1975*a*) for the double-crested cormorant. This may be due to either a real difference between the species, or because of potential errors made in equating meal sizes in captive and wild birds.

Increase in digestive efficiency is related to a decrease in the energetic content of guano which occurred throughout the growth period of the jackass penguin. A similar, but less clear, trend is discernible in the double-crested cormorant (Dunn 1975*a*). Energetic content of guano did not decrease with age in chicks of the Cape gannet (Cooper in prep.). In the jackass penguin it is probable that the increase in digestive efficiency and the decrease in energetic content of guano is related to increasing maturity and therefore efficiency of the digestive organs. Development of digestive organs in the double-crested cormorant is rapid in the first 15 days of growth (Dunn 1975*b*) and the energetic content of guano declined over the same period (Dunn 1975*a*). However, in the European starling (*Sturnus vulgaris*) the energetic content of the faeces increased with age (Westerterp 1973).

The decrease in food intake that occurred between 60 and 70 days of age, prior to fledging, was due to the hand-reared chicks regulating intake by regurgitation of part of the meal. At this time digestive efficiency also decreased. It is possible that a decrease in food intake is a natural phenomenon prior to fledging, as has been recorded in hand-reared puffins (*Fratercula arctica*) (Harris 1976). Another possibility is that the hand-reared chicks had an infection of the alimentary canal, since one chick was later (at *ca.* 100 days of age) diagnosed to be suffering from enteritis.

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